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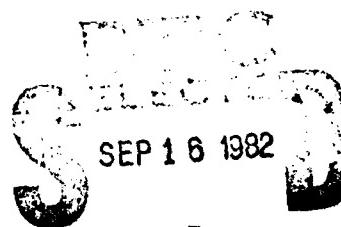
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Technical Report
Department of Nuclear Engineering
Laser Plasma Research Laboratory

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BOUNDARY EFFECTS ON THE DYNAMICS OF
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L. D. Horton and R. M. Gilgenbach
Technical Report #108
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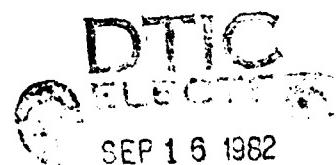
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The dynamics of unbounded and bounded reduced density channels have been characterized by means of ruby laser schlieren photography. These channels are produced by CO_2 laser initiated discharges in clean atmospheric pressure air. Bounded channels exhibit a significant compression in width and earlier onset of fine scale turbulence. These results could impact proposed designs for inertial fusion reactors relying upon reduced density

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channels for particle transport through gas blankets.

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Boundary Effects on the Dynamics

of Channels Generated by Laser-

Initiated Discharges

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The University of Michigan
Ann Arbor, Michigan   48109

The dynamics of unbounded and bounded reduced density channels have been characterized by means of ruby laser schlieren photography. These channels are produced by CO_2 laser initiated discharges in clean atmospheric pressure air. Bounded channels exhibit a significant compression in width and earlier onset of fine scale turbulence. These results could impact proposed designs for inertial fusion reactors relying upon reduced density channels for particle transport through gas blankets.
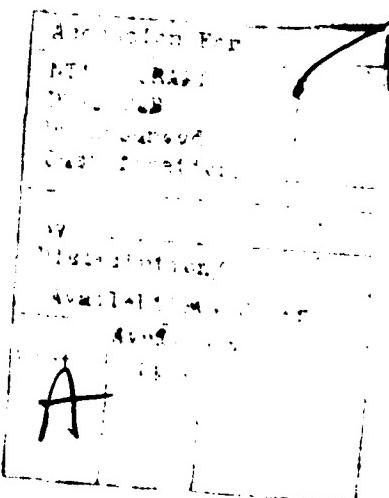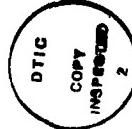
Recent research[1-4] at other laboratories has produced long reduced density channels in atmospheric pressure air and investigated the feasibility of electron beam injection into these channels. Reduced density channels could have important applications to inertial fusion reactors since they provide a means of transporting particle beams through a high density shielding gas blanket.[5-7] Most channel experiments in atmospheric pressure air[1-4] have been performed in essentially unbounded conditions in which the walls were far enough away to have negligible interaction. The effects of solid boundaries on the dynamic behavior of reduced density channels could, however, have important implications on the design of fusion reactors in which channels may be in close proximity to reactor components. Effects which could degrade channel stability include reflected shock waves[7] and boundary induced asymmetries which can decrease the onset time for turbulent convective mixing.[8]

We have employed a ruby laser schlieren diagnostic to investigate the dynamics of laser-initiated discharges and to characterize the channel behavior for three cases:

1) Unbounded channel conditions,

2) A planar insulating boundary on one side of the channel, and

3) Two planar insulating boundaries on opposite
   sides of the channel.

The experimental configuration is depicted sche-
matically in Fig. 1.   A TEA CO_2 laser (Lumonics 601A)
generates a triangular 100 ns pulse of annular cross
section. Calorimetric measurements made downstream of
the propylene absorption cell yielded an incident laser
energy of 12.3 J for these experiments. The discharge
current is supplied by low inductance capacitors
switched through a precision triggered spark gap. In
these experiments the delay between the laser pulse
and the application of high voltage to the electrodes
was 7.6 μs. Schlieren data and open shutter photographs
have verified that, with a 2.5 m focal length mirror,
the laser breakdown beads almost completely bridge the
9 cm gap with a plasma channel, permitting discharge
voltages of 30 kV. For these parameters, the discharge
current is 10 kA, with a ringing period of 2.5 μs. The
ohmic power deposition time is approximately 20 μs,
which is longer than the experiments of Refs. 1-4 but
shorter than the typical 100 μs current pulses in
lightning return strokes.[9] The schlieren photography
system is similar to that reported in Ref. 2, employing
a 20 ns Q-switched ruby laser with a circular aperture
in place of the usual knife edge. By varying the rela-

3

tive delay between the discharge initiation (t_1) and
the ruby laser pulse (t_2) we obtain, on separate discharges,
the temporal evolution of the channel structure. Mul-
tiple schlieren photographs at a given time showed
reproducible discharge-to-discharge behavior. Planar lucite
boundaries were inserted parallel to the discharge axis
to compare the behavior of channels bounded on one or
two sides with unbounded channels. The two boundaries
were positioned symmetrically across the channel approxi-
mately 1.6 cm from the center line of the discharge. The
upper boundary was designed to fit in the open center
of the annular laser beam to minimize interception. The
lower boundary intercepted roughly the same fraction of
the beam as the electrode and the support for the upper
boundary. The data were taken during a single experimental
run so that laser and atmospheric conditions would be
identical for all three cases.

Schlieren photographs for the three cases are com-
pared at significant times in Fig.2. At a time (t)
13 μs after discharge initiation the channels are virtually
identical since the shock waves have not yet impinged on
the boundaries. At this time the discharge current is
still flowing, which accounts for a discernible electrode
effect on the right hand side of the photos. At t=31 μs

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the shock waves have propagated to and reflected from the boundaries, possibly accounting for the increased density gradients at the channel edge. A significant compression of the channel width (30-50%) occurs at 51 μs as the reflected shock waves push the channel edge away from the boundaries. Note that for the single boundary at t=51 μs the channel axis is shifted downward by 0.6 cm. Large scale breakup of the channel becomes apparent at t=71 μs. From 100 μs through 500 μs, bounded channels appear to develop small scale turbulence more rapidly than the unbounded channel.

Theoretical research[8,9] by other investigators has identified convective mixing as the dominant decay mechanism for unbounded reduced density channels. In the case of bounded channels, reflected shocks are also expected to play a major role in channel decay. The data of Fig. 2 suggest that the convective mixing in unbounded channels is associated with longer scale length turbulence, whereas in the bounded cases reflected shock waves appear to drive fine scale turbulence. Further theoretical modeling is required to properly account for boundary effects.

References

1) J. R. Greig, D. W. Koopman, R. F. Fernsler,
   R. E. Pechacek, I. M. Vitkovitsky, and
   A. W. Ali, Phys. Rev. Lett., 41, 174 (1978).

2) M. Raleigh, J. R. Greig, R. E. Pechacek, and
   E. Laikin, NRL Memorandum Report 4380, Feb. 1981.

3) D. W. Koopman, J. R. Greig, R. E. Pechacek,
   A. W. Ali, I. M. Vitkovitsky, and R. F. Fernsler,
   J. DePhysique 2077, Coll. 7, Suppl. 7, Tome 40,
   419 (1979).

4) D. W. Koopman and K. A. Saum, J. Appl. Phys.,
   44 5328 (1973).

5) G. Yonas, Sci. Amer., 239 50 (1978).

6) P. A. Miller, R. I. Butler, M. Cowan, J. R. Freeman,
   J. W. Poukey, T. P. Wright, and G. Yonas, Phys.
   Rev. Lett. 39 92 (1977).

7) R. Courant and K. O. Friedrichs, Supersonic Flow
   and Shock Waves, Interscience Publishers, NY, 1948,
   p. 318.

8) J. M. Picone, J. P. Boris, J. R. Greig, M. Raleigh
   and R. F. Fernsler, NRL Memorandum Report 4472,
   April 1981.

9) R. D. Hill, R. G. Rinken, and H. Dale Wilson,
   J. Atmos, Sci. 37 179 (1980).

Figure Captions

Fig. 1.   Experimental configuration.

Fig. 2.   Sequence of schlieren photographs for:

unbounded channels (left hand column),

channels bounded on upper side (center column),and

channels bounded on two sides (right hand column).

The times at the left hand side of each row

indicate the delay between discharge initiation and

schlieren ruby laser pulse. Magnification is indica-

ted by the 3.2 cm spacing between the upper and

lower boundaries.

MIRROR
F.L. = 250cm

SOLID
BOUNDARIES

SCHLIEREN
FIELD OF VIEW

CURRENT PROBE

TRIGGERED SPARK
GAP SWITCH

BEAM DUMP

ATTENUATOR
CELL

SECTION
A-A

TEA
CO 2
LASER

0.16 μf CAPACITOR

+

−

t₁

H.V.
PULSER

DELAY
GEN.

TO SCHLIEREN
DIAGNOSTIC
SYSTEM

Q-SWITCHED
RUBY LASER

t₂

TRIGGER
GENERATOR

t₀

13 μs

31 μs

51 μs

71 μs

100 μs

200 μs

300 μs

500 μs